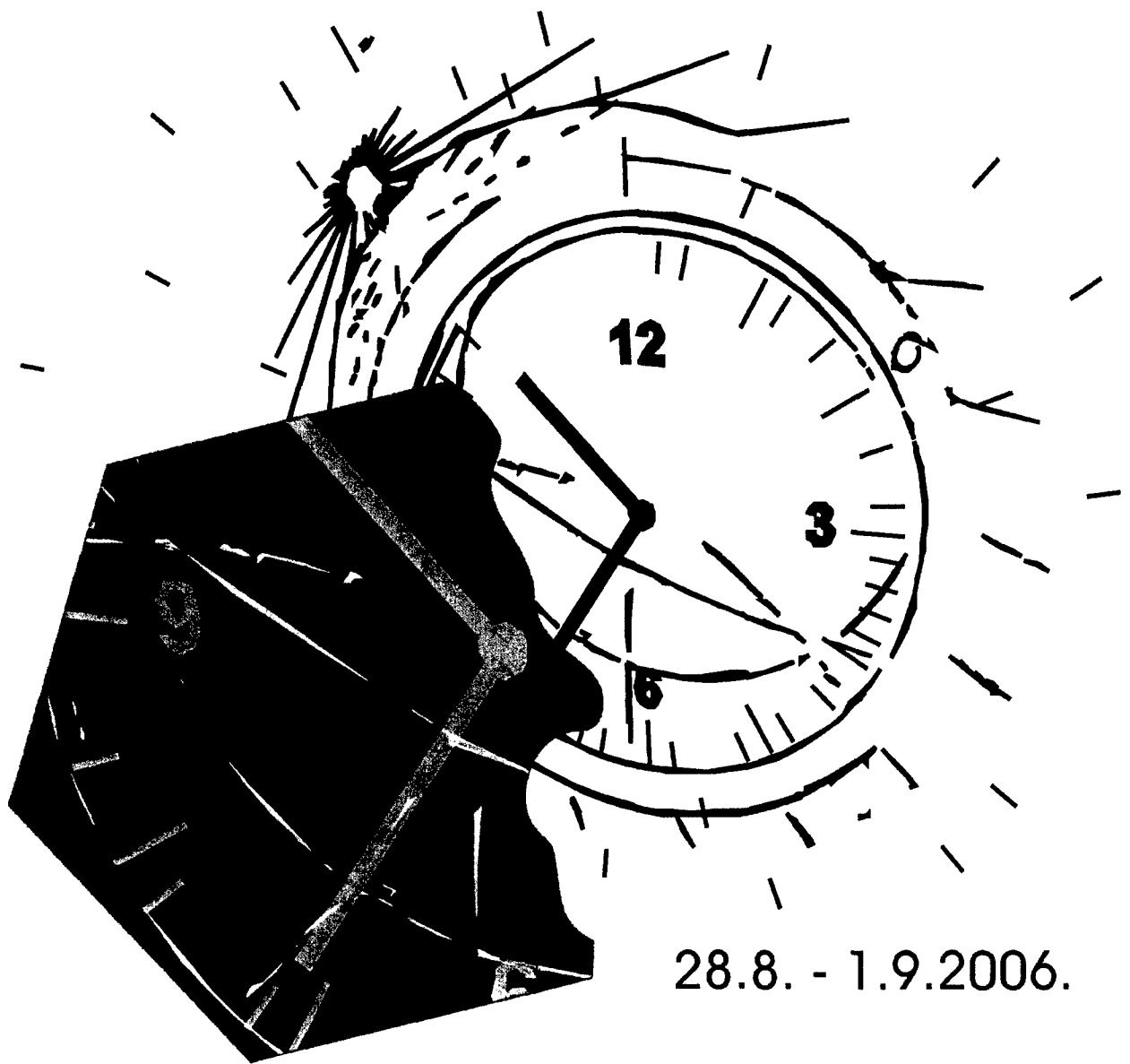


BOOK OF ABSTRACTS

BRIJUNI CONFERENCE
Imaging in Space and Time



28.8. - 1.9.2006.

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14. ABSTRACT The Final Abstracts for the Conference, "Imaging in Space and Time", 28 August 2006 - 1 September 2006 The conference included: A) Acquiring and analyzing data from space. Much of information on distant objects in space is obtained from images in various frequency domains of electromagnetic radiation. Acquiring and analysis of images was reviewed. B) Nanotechnology for manipulation of light: Future advances in fundamental and applied research are envisaged in manipulation of molecules and their conglomerates with electromagnetic radiation. Results in femto and ato second research were reviewed. There were also talks on the possible implementation on quantum computing, for the fast processing of data. C) Images of the basic structure of matter: Elementary particles are the basic elements of matter, and their structure is still somewhat of a mystery. To infer on it one has to extract information data from experiments, which is known as the inversion problem. The status of the field was reviewed.						
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K. Nealsen, USA
G. Pichler, Croatia

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1. Program

Monday, 28. August

8.45-9.00 **S. D. Bosanac** - Introductory remarks

Chairman: **M. Martinis**

9.00-9.40 **J.-P. Luminet**: The Shape of Space, from Black Holes to the Universe

9.40-10.00 discussion

10.00-10.40 **P. Biermann**: The nature of dark matter

10.40-11.00 discussion

11.00-11.20 coffee break

11.20-12.00 **W. Klemperer**: Molecular Imaging and Interstellar Chemistry

12.00-12.20 discussion

LUNCH AND BEACH DISCUSSIONS

Chairman: **T. Živković**

17.30-18.10 **K. Kadija**: Towards the 3-D imaging of the collision region on the femtometer scale

18.10-18.30 discussion

18.30-19.10 **M. Quack**: The current image of the fundamental asymmetry of time and space in molecular dynamics

19.10-19.30 discussion

21.00

Opening of poster session

M. Ramek: Color Perception and Computer-Generated Images

Chairman: **M. Movre**

M. Boyukata: Molecular Dynamics study of Tin, Vn and Crn (n=2-50) clusters

Z. Crljen: Electron Transport in Molecular-wire Junctions

V. Mikuta-Martinis: Relationship between the external stimuli and the internal body clock

J. Gladic, Z. Vucic, D. Lovric: Digital interferometry study of facet kinetics on growing crystals

U. V. Desnica: Imaging of Quantum Dots in 2D and 3D Space

D. Desnica-Frankovic: Vacancy clusters imaging

I. Andelic: Vindicating the Pauling-bond-order concep

M-S. Tomas: Medium effects on the van der Waals (atom-atom) forces

G. Pichler: Treating cesium resonance lines with femtosecond pulse train

R. Beuc: Spectra of alkali dimers adsorbed on the helium nano criostat

I. Matanovic: Quantum description of large amplitude motion in hydrogen bonded systems

M. Pavicic: Graph imaging of quantum detections

M. Pavicic: Interaction-free imaging

V. I. Voloshyn and V. M. Korchinsky: Remote control technologies on land cover elements classification and agrarian resources assessment

V. I. Voloshyn and V. M. Korchinsky: Correction of distortions and improvement of information content in satellite-acquired multi spectral images

M. Buljan: Formation of three-dimensional Ge quantum dot superlattices with post-deposition controllable properties in amorphous SiO₂ matrix

Tuesday, 29. August

Chairman: **A. Sabljic**

9.00-9.40	W. Baumeister: Exploring the inner space of cells by cryoelectron-tomography
9.40-10.00	discussion
10.00-10.40	P. Hering: <i>Facial topometry using pulsed holography</i>
10.40-11.00	discussion
11.00-11.20	coffee break
11.20-12.00	K. Knešaurek: Improving PET/CT imaging by Fourier-wavelet restoration
12.00-12.20	discussion

LUNCH AND BEACH DISCUSSIONS

Chairman: **W. Klemperer**

17.00-17.40	P. Toennies: <i>Solid Helium: An Unusual Liquid! Or Even a Superfluid?</i>
17.40-18.00	discussion
18.00-18.40	S. Leach: Scaling laws in biological evolution
18.40-19.00	discussion

Chairman: **S. D. Bosanac**

21.0	H. Kroto: "Alles" through the Looking Glass
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Wednesday, 30. August

Chairman: **G. Pichler**

9.00-9.40	M. Segev: Nonlinear Waves and Solitons in Photonic Lattices
9.40-10.00	discussion
10.00-10.40	S. Tsai: Imaging the quantum coherence: Readout for superconducting multi-qubit system
10.40-11.00	discussion
11.00-11.20	coffee break
11.20-12.00	T. Ebbesen: Optical diffraction of subwavelength apertures
12.00-12.20	discussion

PICNIC

Chairman: **S. Leach**

21.00	A. Cleeremans: Imaging consciousness: Space and time in the brain
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Chairman: **T. Ebessen**

9.00-9.40	M. Uiberacker: Sampling electron dynamics in atoms in real-time with sub-femtosecond resolution
9.40-10.00	discussion
10.00-10.40	A. Tonomura: Observation of quantum objects and phenomena using electron waves
10.40-11.00	discussion

11.00-11.20	coffee break
11.20-11.40	N. Došlić: Population inversion dynamics in the few-cycle pulse limit
11.40-11.50	discussion
11.50-12.10	T. Ban: Manipulations of the atom velocity with femtosecond laser frequency comb
12.10-12.20	discussion

LUNCH AND BEACH DISCUSSIONS

Chairman: **P. Toennies**

17.00-17.20	M. Martinis: Simulation and visualization of selfgravitating N-particle system
17.20-17.30	discussion
17.30-17.50	V. Zlatic: Nonlinear response of strongly correlated materials to large electrical fields
17.50-18.00	discussion
18.00-18.20	M. Heggie: Imaging the nanospace of dislocations in layered materials.
18.20-18.30	discussion
18.30-18.50	E. Frishman: Control of Spontaneous Emission in the Presence of Collisions
18.50-19.00	discussion
20.30	conference dinner

Friday, 1. September

Chairman: **M. Heggie**

9.00-9.40	S. Berry: Finding What Happens in a Space of Ever So Many Dimensions
9.40-10.00	discussion
10.00-10.40	S. D. Bosanac: Limits of imaging
10.40-11.00	discussion
11.00-11.20	coffee break
11.20-12.00	J. Murrell: Overview of the conference
12.00-12.20	discussion

2. Abstracts

VINDICATING THE PAULING-BOND-ORDER CONCEPT

J. Sedlar¹, Ivana Anđelić^{2,4}, I. Gutman³, D. Vukičević⁴, A. Graovac^{2,4}

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2. The Ruđer Bošković Institute, Bijenička c. 54, 10000 Zagreb, Croatia
3. Faculty of Science, University of Kragujevac, Kragujevac, Serbia
4. Faculty of Natural Sciences, University of Split, Split, Croatia

In the Pauling bond order concept it is assumed that all Kekule structures of a benzenoid molecule contribute equally to the π -electron contents of the carbon-carbon bonds. We modified the Pauling bond order (a) by increasing the weight of a Kekule structure proportional to the number of Fries type hexagons, and (b) by increasing the weights of the Kekule structures that are compatible with Clar aromatic sextet formulas. Improvements in reproducing experimental carbon-carbon bond lengths are insignificant, implying that equal weighting of Kekule structures is more justified than one could anticipate.

References:

- [1] S. J. Cyvin and I. Gutman, *Kekule Structures in Benzenoid Hydrocarbons*, Springer-Verlag, Berlin, 1988.
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- [3] M. Randić, *Chem. Rev.* 103 (2003) 3449.
- [4] L. Pauling, L. O. Brockway and J. Y. Beach, *J. Am. Chem. Soc.* 57 (1935) 2705.
- [5] L. Pauling, *The Nature of the Chemical Bond*, Cornell Univ. Press, Ithaca, 1960.

MANIPULATION OF THE ATOM VELOCITY WITH FEMTOSECOND LASER FREQUENCY COMB

Ticijana Ban, D. Aumiler, H. Skenderović, N. Vujičić, S. Vdović and G. Pichler
Institute of physics, Bijenička 46, Zagreb, Croatia

The frequency spectrum of the pulse train consists of a series of fringes separated by the pulse repetition rate. The fringes are regular in frequency space if the pulses in the pulse train have a defined phase relation relative to each other. In the systems where the atomic coherence relaxation time is longer than the pulse repetition period the atoms interact with the spectrum of the pulse train, and not with the spectrum of a single pulse. Mode-locked, phase-stabilized femtosecond (fs) lasers with high repetition rates produce stabilized wide-bandwidth optical frequency combs (regularly spaced series of sharp lines).

In our recent papers [1,2] we presented the observation of the velocity selective population transfer between the Rb ground state hyperfine levels induced by fs pulse train excitation. We developed a modified direct frequency comb spectroscopy (DFCS) which uses a fixed frequency comb for the $^{85,87}\text{Rb } 5^2S_{1/2} \rightarrow 5^2P_{1/2,3/2}$ excitation (Tsunami mode-locked Ti:sapphire laser with pulse duration of ~ 100 fs and pulse repetition of 80 MHz) and a weak cw scanning probe (TOPTICA DL100, ECDL at 780 nm) for ground levels population monitoring. The Rb($5^2P_{1/2,3/2}$) excited atomic levels have the relaxation times greater than the fs laser repetition period. In the time domain this leads to population and coherence accumulation effects. This corresponds to the interaction of the Rb atoms with the fs frequency comb in the frequency domain. As a result, velocity selective excited state hyperfine level populations are obtained, i.e. the mapping of the frequency comb to the atomic velocity comb. Simultaneously, velocity selective optical pumping of the ground hyperfine levels is achieved. We measured the $^{85,87}\text{Rb}(5^2S_{1/2})$ hyperfine levels population by monitoring the $5^2S_{1/2} \rightarrow 5^2P_{3/2}$ probe laser absorption. Modulations in the $5^2S_{1/2} \rightarrow 5^2P_{3/2}$ hyperfine absorption line profiles are observed as a direct consequence of the velocity selective optical pumping induced by the frequency comb excitation. The $^{85,87}\text{Rb } 5^2S_{1/2} \rightarrow 5^2P_{1/2,3/2}$ fs pulse train excitation of a Doppler broadened rubidium vapor was investigated theoretically in the context of the density-matrix formalism and the results are compared with the experiment. The agreement between theory and experiment is excellent. The dependence of the observed modulations upon the wavelength and power of the fs laser and external magnetic field was investigated experimentally. The expansion of the present investigation to the cesium case was performed.

We foresee an application of the results of this work in the field of spectroscopy of ultracold atoms and the atomic beam experiments. In the systems where Doppler broadening is negligible, by varying the comb optical frequency spectrum it is possible to directly manipulate the fractional populations of hyperfine ground state levels. In addition, we demonstrated that the frequency comb is suitable for velocity selective optical pumping which opens the way to a completely new scheme of laser cooling.

References:

- [1] D. Aumiler, T. Ban, H. Skenderović and G. Pichler, Phys. Rev. Lett. **95**, 233001 (2005).
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EXPLORING THE INNER SPACE OF CELLS BY CRYOELECTRON- TOMOGRAPHY

Wolfgang Baumeister

Max-Planck-Institute of Biochemistry, Am Klopferspitz 18, 82152 Martinsried, Germany

Electron tomography is uniquely suited to obtain three-dimensional images of large pleiomorphic structures, such as supramolecular assemblies, organelles or even whole cells. With the advent of automated data acquisition, facilitated by technological advances (computer-controlled electron microscopes and large area CCD cameras), it has become possible to examine frozen-hydrated samples in a close-to-life state under non-critical electron dose conditions and to attain resolutions which allow the docking of high resolution component structures. High-resolution tomograms of organelles or cells are essentially 3-D images of the cell's entire proteome and should ultimately enable us to map the spatial relationships of macromolecules in a functional cellular context. However, it is no trivial task to retrieve this information because of the poor signal-to-noise ratio of such tomograms and the crowded nature of the cytoplasm and many organelles. De-noising procedures can help to combat noise and to facilitate visualization, but advanced pattern recognition methods are needed for detecting and identifying with high fidelity specific macromolecules based on their structural signature (size and shape).

Experiments with phantom cells, i.e. lipid vesicles encapsulating a known set of proteins have shown that such a template-matching approach is feasible. Once the challenges of obtaining sufficiently good resolution and of creating efficient data-mining algorithms are met, and comprehensive libraries of template structures become available, we will be able to map the supramolecular landscape of cells systematically and thereby provide a new perspective for analyzing the molecular interaction networks underlying higher cellular functions.

FINDING WHAT HAPPENS IN A SPACE OF EVER SO MANY DIMENSIONS

R. Stephen Berry
The University of Chicago

Atomic clusters, nanoscale particles and biomolecules are examples of systems small enough to tempt us to treat them in atomic detail but complex enough to make such an approach look a bit terrifying. This presentation will describe some of the promising ways to extract useful, important information by using microscopic approaches but in variously restricted ways. One is through the use of multiscale simulation, which shows considerable promise especially for biomolecules. Another is through the approach of kinetics, rather than dynamics, specifically by describing the system with a master equation of a particular kind. Instead of constructing and solving a full master equation for the kinetics of motion among all the vast number of minima on a potential surface, one can construct a statistical sample of the information about the topography of the energy landscape and use the corresponding statistical-sample master equation to provide the important rates governing the rearrangements of components of the complex system.

THE NATURE OF DARK MATTER

Peter L. Biermann (Bonn/Tuscaloosa), A. Kusenko (Los Angeles),
F. Munyaneza (London/Bonn and J. Stasielak (Bonn/Cracow)

Dark matter could light up the first stars in the universe if the dark matter is made up of sterile neutrinos. We have shown that sterile neutrino decays could speed up the formation of molecular hydrogen and light up the first stars as early as 20-100 million years after the big bang. The light from these first stars could ionize the interstellar gas by 150-400 million years after the big bang, in accordance with the observations. Formation of central galactic black holes, as well as structure on sub-galactic scales favor some form of warm dark matter, such as sterile neutrinos, as dark matter. The consensus of several indirect pieces of evidence leads one to believe that the long sought-after dark-matter particle may, indeed, be a sterile neutrino. The Galactic center black hole and its mass may provide a crucial limit for the mass of the sterile neutrino: Assuming that the mass of the Galactic Center Black hole is all due to dark matter growth, and that there is little additional baryonic growth, gives a lower limit to the dark matter particle mass. The X-ray emission from neighboring galaxies, the Virgo cluster as well as the X-ray background give an upper limit at almost the same number; the Lyman α -forest gives also a lower limit. This may lead to a decisive step in determining the nature and mass of the dark matter particles, suggesting as one solution a sterile neutrino of a few to a few tens of keV.

LIMITS OF IMAGING

S. Danko Bosanac

R. Boskovic Institute, Zagreb, Croatia

The basic principle of imaging is finding a unique correspondence between a data bank of information and the acquired information. The most primitive correspondence is linking the data bank in brain, say human and observing objects by senses, say eye. Two extremes are at play, a) make the linking very efficient (e.g. by using the same color for the team players of the same club) and b) making the linking very hard (e.g. by using mimicry). Human-made imaging started with the advent of mathematics, and subsequent scientific reasoning. It enabled rationalizing the processes in Nature in terms of images that are produced in the basic three step analysis: choosing initial conditions (from a data bank), solving equations (mathematics) and interpretation of solution (comparison with experiment). Could we be deceived by the interplay of mathematics and experiment? It will be shown that it is easy to be fooled by Nature, because as a general rule Nature uses "mimicry" rather being explicit with the information it provides.

MOLECULAR DYNAMICS STUDY OF Ti_n , V_n AND Cr_n ($n=2-50$) CLUSTERS

Mustafa Büyükat

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Molecular-dynamics simulations have been performed via a Morse type pair potential [1] for predicting atomic geometry, growing pattern, structural stability, energetics and magic sizes of Ti_n , V_n and Cr_n ($n = 2-50$) clusters. Starting from the dimer configuration, following rearrangement collision of the system in fusion process, and absorbing its energy step by step up to 0 K, possible optimal stable structures of the clusters have been generated. This approach serves an efficient alternative to the growing path identification and the optimization techniques [2]. It has been found that titanium, vanadium and chromium clusters prefer to form three-dimensional compact structures in the determined configurations and the appearances of medium sizes are, in general, five fold symmetry on the spherical clusters. Moreover, relevant relations between atomic arrangements in the clusters and the magic sizes have been observed.

Acknowledgements: This work was supported by Erciyes University Research Fund (Project Number: FBA.06.07).

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- [1] S. Hao and N. X. Chen, Phys. Lett. A 297 (2002) 110.
- [2] M. Büyükat, Physica E 33 (2006) 182.

**FORMATION OF THREE-DIMENSIONAL Ge QUANTUM DOT
SUPERLATTICES WITH POST-DEPOSITION CONTROLLABLE
PROPERTIES IN AMORPHOUS SiO₂ MATRIX**

Maja Buljan^{1*}, Uroš V. Desnica¹, Goran Dražić², Mile Ivanda¹, Nikola Radić¹, Pavo
Dubček¹, Krešo Salamon³, Sigrid Bernstorff⁴

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We report the observation of spontaneous self-organization of Ge quantum dots into three-dimensional hexagonal superlattices within the amorphous SiO₂ matrix. Observed superlattices have tunable unit-cell parameters, QD shape and phase, as well as very narrow QD size-distribution and high density. Self-organization is achieved within a very restricted region of the magnetron deposition parameters of (Ge+SiO₂)/SiO₂ multilayers, while the superlattice properties are simply controlled by temperature of the post-deposition annealing. We supported our claims with several high-quality methods: Grazing Incidence Small Angle X-ray Scattering, Transmission Electron Microscope and Raman spectroscopy.

IMAGING CONSCIOUSNESS: SPACE AND TIME IN THE BRAIN

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BELGIUM

One way to approach the problem of consciousness involves exploring the differences between conscious and unconscious cognition. Striking dissociations between subjective experience and behaviour have now been reported in various domains, from memory to learning, from perception to action. Yet, the extent to which information processing can take place without consciousness remains controversial, in part because of the substantial methodological challenges associated with demonstrating unconscious cognition; in part because of conceptual differences in the manner in which such dissociations are interpreted. Methods such as functional Magnetic Resonance Imaging or Magnetoencephalography now make it possible to watch the brain in action with spatial and temporal resolutions that are such that one can meaningfully engage in a "search for the neural correlates of consciousness". Yet, many challenges remain, for consciousness is not a "single thing", but rather a dynamical process that is extended both in space and in time.

In this talk, I overview recent relevant findings in the domain, and sketch a novel conceptual framework that takes it as a starting point that conscious and unconscious cognition are rooted in the same set of learning and processing mechanisms. On this view, the extent to which a representation is conscious depends in a graded manner on properties such as its stability in time or its strength. Crucially, these properties are accrued as a result of learning, which is in turn viewed as a mandatory process that always accompanies information processing.

An important implication of these ideas is that consciousness takes time, time for the massively recurrent processing characteristic of neural computation to settle into stable states as a result of global constraint satisfaction. To support this hypothesis, I will report on several experiments, in the domains of learning, conditioning, and action, in which we manipulated the temporal relationships between events and measured the extent to which such manipulations influence the extent to which processing is conscious.

VACANCY CLUSTERS IMAGING

I. Dunja. Desnica-Franković¹, P. Dubček¹, M. Buljan¹, U.V. Desnica¹, S Bernstorff²

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²Sincrotrone Trieste, Basovizza, Italy

Grazing incidence small angle scattering of X-rays (GISAXS) is a very suitable method for studying implantation induced structural modifications, since distinctive spectra were obtained in the whole range of doses, from the very lightly damaged material modified by 1×10^{12} ion/cm² fluences, and through a number of different phases as the implant doses were increased. GISAXS, which is sensitive to the electron density fluctuations, may monitor the process of implantation-induced vacancy clustering, may expose the existence of nano-voids in the material and provide a means to establish the concentration, sizes and size distribution of voids in thin amorphous layers that are otherwise difficult to probe.

In this study, GISAXS was used to analyze structural modifications in implantation-damaged Ge. The applied doses were ranging from 1×10^{12} to 3×10^{16} ion/cm². During the implantation process, in the region of maximal damage and maximal density of vacancy production, vacancies agglomerate forming quasi-particles. The sizes and shape of such quasi-particles were determined from the 1D cut of 2D GISAXS patterns using a Guinier-plot analysis. On several spectra, the Local Monodisperse Approximation (LMA) was applicable for the analysis of shape and size as well as the size distribution of nano-clusters.

For even higher doses nano-clusters agglomerate into large voids, of broad size distribution; it is an onset of porosity, which completely dominates in the 3×10^{16} cm⁻²-dose sample. The whole process was monitored through the proper analysis and modeling of corresponding 2D GISAXS spectra.

IMAGING OF QUANTUM DOTS IN 2D AND 3D SPACE

Uroš V. Desnica¹, M. Buljan¹, P. Dubcek¹, I.D. Desnica Frankovic¹, N. Radic¹, M. Ivanda¹, Z. Siketic¹, I. Bogdanovic-Radovic¹, G. Dražić², K. Salamon³, S. Bernstorff⁴

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Grazing incidence small angle x-ray scattering (GISAXS) and Transmission Electron Microscope (TEM) were applied to image Ge Quantum Dots (QDs) synthesized in SiO₂ amorphous matrix. GISAXS provides information (in inverse space, from the large area of the samples with excellent statistics) about size and shape of QDs as well as about their spatial correlations.

Ge QDs were formed in multilayered films deposited by magnetron sputtering in form of 20 bi-layers on either SiO₂ or Si substrate. Each bi-layer consisted of a layer of co-sputtered mixture of 40%mol Ge and 60%mol SiO₂ ('active layer'), and a layer of pure SiO₂, serving as the spacer between 'active' layers. Deposition temperature, T_d, ranged from room temperature to 700 °C. As-deposited samples were subsequently thermally annealed up to T_a = 1000 °C. The 2D GISAXS patterns, besides detecting bi-layered structure, revealed the formation of Ge QDs in deposited films and their possible ordering. The shape and the size of Ge QDs were found to be strongly dependent on both T_d and T_a. The average size of QDs can be controlled by the thickness of the Ge-SiO₂ co-sputtered layer and T_a, while the ordering of QDs depended strongly on T_d and on the thickness of the spacer layer. The synthesis of good quality spherical crystalline Ge QDs was achieved by T_d up to 600 °C followed by post-deposition annealing in 700-800 °C range. In contrast, the deposition at T_d=700 °C results in loss of most of Ge atoms and formation of non-spherical, faceted Ge QDs. For T_a=500 °C the 2D ordering of Ge QDs occurs already during deposition, with no loss of Ge. For a very narrow range of deposition conditions (T_a=500 °C and spacer layer 7 nm thick) 3D ordering of Ge QDs into hexagonal superlattice was achieved.

POPULATION INVERSION DYNAMICS IN THE FEW-CYCLE PULSE LIMIT

Nađa Došlić

Ruđer Bošković Institute, Zagreb, Croatia

We shall discuss the population inversion in a two-level system generated by sub-one-cycle pulse excitation. Specifically, the effect that the time derivative of the pulse envelope has on the Rabi dynamics is explored. We find a shortening of the Rabi inversion period and show that complete inversion is unobtainable under resonant, ultrashort pulse condition. The impact of non-resonant and carrier-envelope phase dependent effects on the dynamics of two-level systems is studied numerically, and conditions for complete population inversion are derived.

The second part of the talk focuses on multi-level systems. We present a zero-net-force modification of the optimal control algorithm which allows us to extend the algorithm into the ultrashort pulse domain. By combining the analysis of the control landscapes and that of optimal control theory, we were able to formulate a general mechanism suitable for laser control by ultrashort pulses. The strategy consists of a superposition of two π -pulses with carrier envelope phases of $\phi = \pi/2$. The first pulse is effectively in resonance with the targeted transition, while the second one, fired at around the minimum of the first pulse second lobe removes leaking to the dipole-coupled background state. In order to compensate for the pulses ultrashort duration, the carrier frequencies of both pulses are red-shifted from the spectroscopic resonance.

OPTICAL DIFFRACTION OF SUBWAVELENGTH APERTURES

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An aperture in a screen is probably the simplest optical element one could imagine and it has been an object of curiosity and technology since the Antiquity, well before it was scientifically analyzed. In the middle of the 17th century, Grimaldi first described diffraction of a circular aperture contributing to the foundation of classical optics. Despite their simplicity, such apertures have remained the object of scientific studies ever since as an accurate description of their optical properties has turned out to be extremely difficult. In the 20th century, Bethe treated the diffractive optics of subwavelength apertures in an idealized metallic screen which became the reference associated with the miniaturisation of optical elements and the development of modern characterization tools such near-field scanning optical microscopes. In the past decade new experimental results reveal that the real subwavelength apertures in metal films can have properties that are very different from the earlier theoretical predictions due to the involvement of surface plasmons in the transmission process. Most notably the transmission intensity can be much greater than Bethe's prediction and the geometrical diffraction is far from isotropic at the exit of the aperture. This has implications in a variety of areas including the subwavelength lithographic transfer of images, near-field imaging and the observation of single molecule dynamics.

QUANTUM COMPUTING VIA LOCAL CONTROL

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The central goal of quantum computing is the creation of a desired unitary transformation, which is identified with the computation. As was recently shown [Sklarz and Tannor '04, '06], local control theory can be used to calculate fields that will produce these transformations. In contrast to strategies using optimal control theory, the present approach maintains the system at the computational sub-space at intermediate times, thus avoiding unwanted decay processes and sensitivity to the initial state of the mediating sub-space.

We consider a system with direct-product structure with respect to the computational register and mediating states, where dynamics takes place in Liouville space. This implementation leads to "virtual entanglement" - in which second order transitions take place through entangled states, yet leave the sub-systems nearly separable.

In this work we show how to produce arbitrary entangling two-qubit gates directly using this approach. The advantage of this method is that it avoids the need to produce unitary gates as a sequence of (perhaps a large number of) basis gate operations, thus increasing the robustness and fidelity of the computation.

IMAGING THE NANOSPACE OF DISLOCATIONS IN LAYERED MATERIALS

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The formation and movement of dislocations control the plastic behaviour of materials. In materials such as the cores of graphite moderated nuclear reactors, direct observation of material properties with time and neutron dose is impossible – due to constraints of space, heat, irradiation and reactor safety in general. Extrapolation from materials test reactor data is necessary and such extrapolation must have sound theoretical foundations. First principles total energy calculations and computer visualisation affords a privileged view of irradiated graphite that has radically altered our understanding of the dramatic changes that occur on irradiation. The biggest single factor in this change is the revelation that basal dislocations, and not point defect migration and clustering, are responsible for most property changes. The effects are, by and large, unique to layered materials and illustrate the need for clear symbolic/diagrammatic descriptions of dislocations as well as for clear physical representations.

The observations should provide insight for layered materials in general from clays to ceramic superconductors under irradiation and under mechanical deformation.

FACIAL TOPOMETRY USING PULSED HOLOGRAPHY

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<http://www.caesar.de/holographyandlaser.0.html>

Planning, simulation and documentation of interventions in maxillofacial surgery requires high resolving soft tissue information of the human face. We extract this information from pulsed holograms, which allow a single pulse recording of the whole face. The ultra fast capture time (20 ns) avoids motion artefacts even when the patient moves.

After automated wet-chemical processing, the hologram is optically reconstructed with a cw-laser. The real image is digitized into a set of two-dimensional projections. By digital image processing the in-focus parts of these projections are identified and combined into a three-dimensional digital model. Besides the topometric information, a high resolving monochromic texture is extracted from the real image, providing a pixel-precise colouring for the digital model.

With mirror arrangements we expand the measuring possibilities of the technique. The placement of mirrors enables a capture of the face in a reclined position. With this approach we quantify soft tissue displacements comparing the reclined and upright portraits of a person. In another approach we simultaneous capture the normal portrait along with two mirror views with one single laser pulse. Combining these views offers a recording range of approximately 270 degrees.

In addition to the medical application, high resolving and textured computer models of faces are of tremendous importance for facial reconstruction in anthropology, forensic science and archaeology.

TOWARDS THE 3-D IMAGING OF THE COLLISION REGION ON THE FEMTOMETER SCALE

Krešo Kadija
Rudjer Bošković Institute, Zagreb, Croatia

A brief review will be given on the discovery of the HBT (Hanbury-Brown and Twiss) effect, where photons were exploited to determine stellar dimensions, and its generalized application in high energy physics, where hadrons are used to determine spatio-temporal characteristics of hadronic sources. Interesting and inspiring new directions will be highlighted, including source imaging methods at the femtometer scale.

MOLECULAR IMAGING AND INTERSTELLAR CHEMISTRY

William Klemperer
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We examine the spatial correlation of molecular and atomic species with a view toward obtaining tests of kinetic schemes of molecule formation under the wide variety of conditions that occur. We speculate on some schemes of molecule formation. We also will discuss molecular abundances determined by emission spectra.

IMPROVING PET/CT IMAGING BY FOURIER-WAVELET RESTORATION

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Recently, positron emission tomography (PET) has become a very well recognized diagnostic imaging method in oncology, cardiac imaging and neuroimaging. Putting together computed tomography (CT) with PET in combined PET/CT systems enables us, in one procedure, to obtain both functional PET images and anatomical CT images in almost perfect coregistration. However, PET images, although extremely useful in diagnosis, treatment planning and in defining prognosis, still suffer from a high level of noise and relatively limited resolution due to the random coincidences, scatter and attenuation of 511 keV photons. To address these limitations, the restoration approach has been successfully used in nuclear medicine imaging for various applications. However, the restoration process is an ill-conditioned process, which has a tendency to significantly increase the amount of noise in the restored images. To address this problem a, new hybrid Fourier-wavelet deconvolution restoration technique has been developed. Here, the Fourier-wavelet deconvolution restoration technique using the Butterworth filter in the Fourier domain and Daubechies wavelet functions, order 2 was implemented. Wavelet noise suppression was applied by a hard threshold.

We have applied our hybrid Fourier-wavelet restoration technique in the whole-body lung 2D PET oncology imaging and in the 3D brain PET imaging, mostly for Alzheimer's disease cases. The approach, with slight modification of the filters, can also be applied in PET imaging of other organs such as cardiac perfusion imaging. The results of our studies show an average 25% increase in contrast in lung lesions, with a 2% increase in noise in the restored images. In brain imaging the results are very similar. The typical increase in contrast in brain PET imaging was 19%, while the restored images had practically the same amount of noise ($\pm 3\%$) as the original images. Our results show that the quality and quantification of the 3D brain and 2D lungs PET images can be significantly improved by Fourier-wavelet (FTW) restoration filtering.

SCALING LAWS IN BIOLOGICAL EVOLUTION

Sydney Leach

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My talk will first of all deal with power laws in present day biological systems which thus represent a “static” picture, a photograph/image of present day biological systems, after evolution has done its work. This is real science. It is exemplified by the original work of Kleiber (1932) who plotted the basal metabolic rate of mammals and birds against mass. Recent studies by Geoffrey West and James Brown of the Santa Fe Institute and Los Alamos Laboratory have much extended this type of work to many biological systems.

I will then go from the static biological picture to time-dependent phenomena by introducing scaling laws in evolutionary contexts. The ones I have chosen, although based on science, are permeated with the more metaphysical concept of the acceleration of history. This discussion will be based on the studies of *Henry Adams*, who essentially introduced the term “acceleration of history” in 1904, *Sergei Kapitza*, the physicist and polymath, who studied human population growth, and extended his study to large-scale historical events (1996), and *Graeme Snooks* (Australian social scientist, 2005) who is concerned with scaling law expressions involving mass extinction episodes in the history of evolution, as is *A.D.Panov* (Russian nuclear physicist, 2005) who extends the study to human and historical evolution as well as to the prebiological era.

Many of the premises in these studies are debatable and some, such as those leading to evaluations concerning the origin of life, are frankly on the borderline of science fiction. Nevertheless, I offer these studies to you as likely to arouse reflection, discussion and debate on a host of fascinating subjects.

THE SHAPE OF SPACE, FROM BLACK HOLES TO THE UNIVERSE

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The description of the shape of our physical space at various scales (length scales or energy scales) involves a rich variety of geometrical models, each depending on the underlying physical theory. Imaging distorted space and time by gravitational and quantum fields is a big challenge of modern fundamental physics. I shall discuss such space representations for describing the shape of space around black holes, next the global shape of our universe in the framework of cosmic topology, and eventually give hints on the shape of space-time at the quantum scale. Striking movies and color visualizations will be displayed.

SIMULATION AND VISUALIZATION OF SELFGRAVITATING N-PARTICLE SYSTEM

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When we observe the universe we see structures on essentially all scales. The large distribution of matter in the universe as traced by visible (red shift survey) galaxy structures shows a complex irregular pattern, characterized by clusters of galaxies which are organized in filaments and walls around large voids. The most widely used tool to study these structures is by means of gravitational N-body simulations [1]. During simulation, the structures form and evolve from a given initial state (generally unknown) according to the law of Newtonian gravity. The long-range character of the gravity, however, produces several peculiarities in statistical behaviors of the system that are totally different from usual systems. These are the ensembles inequivalence, negative specific heat, non-extensive thermodynamics, strong dependence on N, large fluctuations, self-consistent chaos, slow relaxation, and formation of structures. Some years ago a detailed two point correlation analysis of galaxy clustering [2] showed that galaxy correlation properties are similar to those of a fractal, self-similar object with fractal dimension $D \sim 2$. Since the evidence for scale-invariance of highly irregular galaxy distributions with large structures and voids strongly depends on the appropriate choice of two point correlation analysis, we studied various two point correlation estimators to find that only Ripley's K-function minus estimator gives the correct fractal dimension of an arbitrary 3-d distribution of point particles. The test is performed first on the Menger's sponge model with a known fractal distribution of point particles, for which we also developed a small 3-d visualization program RoPo (Rotate Points) [3]. K-minus estimator was then applied to 2dF (Two-Degree Field) catalogue data.

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- [3] Available upon request from martinis@irb.hr. Bugs should be reported to marin.sosic@zg.htnet.hr

QUANTUM DESCRIPTION OF LARGE AMPLITUDE MOTION IN HYDROGEN BONDED SYSTEMS

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We present two quantum methods capable of describing the Large Amplitude internal motion (LAM) in H-bonded Systems. The solution of the multidimensional Schrödinger equation is achieved both in localized and collective LAM coordinates. First approach uses a localized internal coordinates representation of the Hamiltonian in which the coordinate dependence of the Wilson G-matrix needs to be taken into account [1]. The second approach is based on the definition of the minimum energy path (MEP). In this approach the collective LAM coordinates are constructed as a linear combination of a few critical geometries on the MEP in such a way to best reproduce the system geometries and energetics on the MEP [2,3]. The remaining orthogonal degrees of freedom are linearized and the dynamics is treated within the Reaction Surface Hamiltonian approach.

The methods were applied to H-transfer reactions in acetylacetone (ACAC) and the formic acid dimer (FAD). Tunnelling splitting for the zero-point level and for the lowest vibrationally excited level of the antisymmetric C-O stretch vibration in FAD were calculated and confronted with the high resolution experiments by Madeja and Havenith [4].

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RELATIONSHIP BETWEEN THE EXTERNAL STIMULI AND THE INTERNAL BODY CLOCK

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Biosystems have tendency to repeat their activities in time. These cycles are very important in many essential biological processes that occur in a "scheduled" fashion (eating, sleeping, cellular regeneration...). **Chronobiology** is the branch of science that examines these time-related phenomena in living organisms and quantifies mechanisms of biological time structure (circadian, circavital and circannual rhythm). The most important rhythm is the "**circadian**" rhythm which refers to the (roughly) 24-hour daily biological cycle. In this research we have studied the influence of the external oscillating phenomena on the circadian rhythm in humans (the "internal body clock"). Some very important oscillating parameters like immunoglobulin (IgA, IgG and IgM), the daily variation of hormones (cortisol), the blood pressure and the heart frequency are examined. The study was performed on the group of 22 young men in the age between 20 and 23 and experimental results were analysed using ANalysis Of VAriance (ANOVA) and some other tests. Our analysis confirmed that changes in the oscillating character of above parameters are strongly correlated with the external stimuli.

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SPECTRA OF ALKALI DIMMERS ON THE HELIUM NANO CRYOSTAT

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Cold nanodroplets (or clusters) of about 10^4 helium atoms have been shown to provide a weakly interacting, low temperature environment of 0.37 K (nano cryostat) for the formation and spectroscopy of molecules. Alkali metal atoms picked up by a beam of helium nanodroplets, remain on the helium surface where they „skate“ around and form molecules in cold collisions. After the formation of molecules with a certain large binding energy, this energy is released into the surrounding helium cluster and causes evaporation of helium atoms, one helium atom for every 5 cm^{-1} of energy. As a result, helium droplets loaded with weakly bound molecules are observed at larger abundance downstream in the helium cluster beam than droplets loaded with strongly bound molecules.

Due to the low temperature of the helium environment, only the lowest vibrational state is populated in each case. This enables easy quantum simulation of absorption spectra if the relevant potential curves are available. Few additional approximations lead to analytical formulas [1,2] which are suitable for the analysis of the experimental spectra. Our spectral simulations were performed by using the set of potential curves calculated in Hund's case (a). The direct comparison with experimental observation was made for Cs_2 molecule [3]. Recently, this method was applied for heteronuclear alkali molecules KRb [4] and RbCs [5] stabilized on the cold helium droplet. The results will be shown and discussed.

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GRAPH IMAGING OF QUANTUM DETECTIONS

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We present a generalized and exhaustive method of finding the directions of the quantization axes of the measured eigenstates within experiments which have no classical counterparts. The method relies on a constructive and exhaustive definition of sets of such directions (which we call Kochen-Specker vectors) in a Hilbert space of any dimension as well as of all the remaining vectors of the space. Kochen-Specker vectors are elements of any set of orthonormal states, i.e., vectors in n -dim Hilbert space, $n > 2$ to which it is impossible to assign 1s and 0s in such a way that no two mutually orthogonal vectors from the set are both assigned 1 and that not all mutually orthogonal vectors are assigned 0. Our constructive definition of such Kochen-Specker vectors is based on imaging of nonlinear equations that define the geometry of the vectors to linear graphs, the so-called MMP diagrams. Thus we substitute solving nonlinear equations by checking conditions imposed on the corresponding graphs. In doing so we reduce the exponentially complex task of solving nonlinear equations to a polynomial complex task of generating and sorting the graph images of the equations.

The latter procedure invokes a 2-dimensional meta-imaging - a representation of graphs as figures on which we can define states and find final solutions by rejecting all those ones that allow them. The algorithms are limited neither by the number of dimensions nor by the number of vectors and can also be used as a general method for solving particular nonlinear equations in any other imaginable application. We obtained thousands of new Kochen-Specker vectors in practically no time. While solving systems of nonlinear equations by brute force would take ages and ages of the Universe, generation and elimination of graphs take minutes and hours.

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INTERACTION-FREE IMAGING

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We consider imaging of atoms - i.e. their states - without transferring a single quantum of energy to the photons that serve as a carriers of the imaging. The process of imaging is carried out by atoms taking over the control of photon states depending on the states they are themselves in. In the quantum computation terminology, we obtain a nondestructive interaction-free atom-photon CNOT gate, i.e., a single atom device for manipulation of photon qubits without transferring any energy to them. The gate can also be used "in reverse" for controlling superposition of atom states, i.e., for a preparation of atom states in an interaction-free way.

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TREATING CESIUM RESONANCE LINES WITH FEMTOSECOND PULSE TRAIN

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We present results of recent experiments when cesium vapor were illuminated by the femtosecond laser frequency comb centered at either D2 line at 852 nm or D1 line at 894 nm. This action changed the usual Doppler profile into very peculiar profile in which periodic structure can be observed by cw laser scanning probe. The periodic structure reflected the frequency spectrum of the pulse train consisting of a series of fringes separated by the pulse repetition rate. In cesium system the atomic coherence relaxation time is longer than the laser pulse repetition period. Cs atoms interact with the spectrum of the pulse train, and not with the spectrum of a single pulse. This open up a possibility for the high resolution spectroscopy [1,2], where the observed linewidths are much less than the Fouriertransform limit of the individual pulse in the train.

In our recent papers [3,4] we presented the observation of the velocity selective population transfer between the Rb ground state hyperfine levels induced by fs pulse train excitation. We developed a modified direct frequency comb spectroscopy (DFCS) which uses a fixed frequency comb for the $^{85,87}\text{Rb } 5^2\text{S}_{1/2} \rightarrow 5^2\text{P}_{1/2,3/2}$ excitation (Tsunami modelocked Ti:sapphire laser with pulse duration of 100 fs and pulse repetition of 80 MHz) and a weak cw scanning probe (TOPTICA DL100, ECDL at 780 nm) for ground levels population monitoring. The Rb($5^2\text{P}_{1/2,3/2}$) excited atomic levels have the relaxation times greater than the fs laser repetition period.

We shall present velocity selective optical pumping of the ground hyperfine levels in cesium atoms achieved by femtosecond laser oscillator. Modulations in the hyperfine absorption line profiles are observed as a direct consequence of the velocity selective optical pumping induced by the frequency comb excitation. In addition, we show the results of the use of a hyperfine Cs filter, which selectively absorbs frequency comb lines over the Doppler profile.

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THE CURRENT IMAGE OF THE FUNDAMENTAL ASYMMETRY OF TIME AND SPACE IN MOLECULAR DYNAMICS

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The traditional image of time and space in molecular dynamics pictured them in two equivalent mirror image forms each, with a space inverted and a time reversed system being equivalent to the original systems before taking the mirror image. In technical terms this corresponds to the symmetry under space inversion and time reversal in the dynamical system. Symmetries can furthermore be related to conservation laws and 'nonobservables'. The inversion symmetry of space, for instance, corresponds to parity conservation. Since the discovery of parity violation 50 years ago in nuclear and high energy physics, we know that the mirror image of a molecule does not exactly correspond to the physically realized enantiomer, or 'mirror image isomer', thus the real image shows a slight asymmetry, which also is observable as a slight energy difference between enantiomers of chiral molecules.

The spectroscopic observation of the small parity violating energy difference $\Delta_{pv}E$ between the two enantiomers of a chiral molecule predicted within the framework of the standard model of high energy physics remains one of the greatest challenges of current molecular physics with possible consequences also for biomolecular evolution [1-3].

A possible, very difficult spectroscopic experiment has been proposed by us about two decades ago [4,5]. The first requirement for such an experiment is the analysis of rovibrationally resolved optical (infrared or visible or ultraviolet) spectra of chiral molecules and the experimental breakthrough achieving this goal arose from work in our group around 1995 (see refs 1-3 for reviews). A major theoretical breakthrough occurred about at the same time, when we discovered that earlier estimates for $\Delta_{pv}E$ were too low by one to two orders of magnitude for the prototype molecules H_2O_2 and H_2S_2 and also other chiral molecules [6-8]. This striking result has in the meantime been reconfirmed by a variety of other quantum chemical techniques and from other theoretical groups and can be considered reliable (for a recent review see [1-3]). Still the predicted energy differences remain very small; in the Attohartree range $10^{-18} E_h$ to $10^{-15} E_h$ or 2.6 pJ mol^{-1} to 2.6 nJ mol^{-1} is fairly typical, depending on the molecule. The corresponding spectroscopic challenge is substantial. In the lecture we shall report about current experimental and theoretical work of the Zurich group (see also [9,10]) also in relation to work of other groups. If time permits we will also discuss possible CPT tests according to our scheme [1,11]. This, indeed, would lead to a completely revised image of time and space asymmetries in physics and chemistry.

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NONLINEAR WAVES AND SOLITONS IN PHOTONIC LATTICES

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The recent progress on waves in nonlinear photonic lattices will be reviewed, with an emphasis on universal ideas that apply to any nonlinear periodic systems in which waves propagate.

SOLID HELIUM: AN UNUSUAL "LIQUID" OR EVEN A SUPERFLUID?

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A solid is generally considered to be rigid and hard with its atomic-sized constituents distinctly localized in well-defined positions. Solid helium shows sharp X-ray diffraction peaks and the expected phonon dispersion curves from neutron diffraction. Helium on the other hand is the most compressible of all solids and is the only substance which remains liquid at atmospheric pressure down to null so that solidification occurs only at an applied pressure greater than about 25 bar. Both these anomalies were attributed by London (1954) and others to the large zero point energy resulting from the weak van der Waals potential and low mass.

In 1969 Andreev and Lifshitz [1] pointed out that zero point oscillations may induce a sufficient concentration of defects (vacancies and/or interstitials) to allow their Bose condensation to produce a supersolid phase with frictionless flow albeit at very low velocities. Despite many further theoretical investigations and experimental attempts [2] no convincing evidence has been obtained for the existence of a supersolid. This situation changed when in 2004 Kim and Chan [3-4] presented evidence for an anomalous abrupt drop in the moment of inertia of the solid at temperatures below about 0.1 K over a wide range of pressures. At present however the interpretation in terms of the supersolid state is highly controversial. [5] One of the issues is whether the annealing of the crystal was sufficient to assure its absolute perfection and purity. Another route to the supersolid was suggested by Galli and Reatto [6] who predicted that, independent of the existence of the supersolid near absolute zero, the rapid increase of the vacancy concentration with temperature may induce a (re-entrant) supersolid phase just above the melting curve and below the upper lambda point.

Recently in our laboratory a new unexpected phenomenon was observed in the expansion of solid helium through a small orifice into vacuum [7]. On raising the pressure or lowering the temperature so that the liquid in the source chamber solidified the flow continued unabated and moreover a reproducible sequence of bursts with a constant period of between 0 and several hundred seconds was observed. This new phenomenon, called the geyser effect, is attributed to the encroachment of vacancies from the solid/liquid (s/l) interface into the solid, followed by a sudden collapse. At temperatures below 1.76 K dramatic deviations suggest the formation of a new phase of solid ^4He induced by the excess vacancies. It is interesting to find that these anomalies are consistent with one of the scenarios of Galli and Reatto proposed for the occurrence of a vacancy induced supersolid.

Several experiments have been undertaken to better understand these new phenomenon. In one set of experiments small percent concentrations of ^3He were found to have a dramatic effect on the anomalous behavior [8]. Since ^3He is known to affect the vacancies this observation confirms the quantum origin of the anomalous behavior. In other experiments a new arrangement consisting of a 0.11 mm dia and 14 mm long channel with pressure sensors up and downstream was used to gain more information. For this arrangement a very similar geyser behavior was found and investigated over a wide range of pressures and temperatures [9].

These results, although not yet fully understood, raise many intriguing questions about the strange hydrodynamic behavior of this unusual quantum solid. Although it is still too early to establish the existence of a supersolid. It is hoped that the recent resurgence of related theoretical investigations will ultimately provide explanations.

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MEDIUM EFFECTS ON THE VAN DER WAALS FORCE

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Although it is known for quite some time that the surrounding medium [1] and the presence of nearby boundaries [2] have strong effects on the van der Waals (atom-atom) interaction, considerations of the combined medium and boundary effects in realistic systems on it appeared only recently [3,4]. In this work, we consider the medium effects on the van der Waals interaction potential (force) between two ground-state atoms embedded in adjacent semi-infinite magnetodielectric media. In this case, in addition of being screened by the surrounding media in a way similar to that of the van der Waals force in a single medium [5], the force is further reduced and becomes anisotropic owing to the transmission/refraction of the vacuum field across the interface. We also calculate the Casimir-Polder force on an atom A arising from the uniform distribution of the atoms B in the medium across the interface. Comparison of this force with the corresponding result deduced from the Casimir force on a thin slab in front of a composite medium obeying the Clausius-Mossotti relation, suggests a hint on how to improve a well-known formula for the van der Waals potential [2,3,4] with respect to the local-field effects.

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OBSERVATION OF QUANTUM OBJECTS AND PHENOMENA USING ELECTRON WAVES

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Quantum mechanics, which was first born as a law describing the behavior of electrons inside atoms, now provides the basis for nearly all physical theories. Although there still remained unsettled problems at its very foundation, recent technological developments have made it possible to experimentally examine some of these problems. Quantum phenomena are now attracting attention not only in scientific fields but also in fields seeking practical applications to electronic devices as obstacles to the further improvement of device performances and as pathfinders for future devices. We have successively developed brighter field-emission electron beams over 30 years and used them to directly observe quantum phenomena by using the wave nature of electrons. Every time we developed a brighter electron beam, new applications opened up [1]. We can now carry out fundamental experiments in quantum mechanics that were once regarded as thought experiments. Examples include a single-electron build-up of an interference pattern and conclusive experiments on the Aharonov-Bohm effect. In addition, visualizing magnetic lines of force in h/e flux units by interference microscopy and dynamically observing quantized vortices in superconductors by Lorentz microscopy have become possible. These methods are expected to become a useful tool for investigating quantum phenomena that have begun to appear at many places in microscopic regions including electronic devices.

Using Lorentz microscopy, various kinds of vortex motions in superconductors with pinning centers were observed. The vortex motions in niobium thin films were elastic, plastic [1] and even rectified [2] depending on the distributions and strengths of the pinning centers, and also on the sample temperatures. In high- T_c superconductors, when the sample temperature decreased, the vortex motion changed from hopping to slow migration due to the pinning effect of atomic-size defects, which increased to hide even the pinning effect of columnar defects [3]. We also used this technique to directly observe the mechanisms of unconventional arrangements of vortices, such as the chain state of vortices in YBCO and the chain-lattice state in Bi-2212, at an inclined magnetic field [4].

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IMAGING THE QUANTUM COHERENCE: READOUT FOR SUPERCONDUCTING MULTI-QUBIT SYSTEM

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Imaging can be defined as the recording of spatial distributions of the certain characteristics of the subject through certain sensing techniques. However, in quantum coherent system, the imaging is not as straightforward as in the classical system. The act of sensing applied to the quantum subject would destroy the coherence of the system. In quantum information processing, the states of the qubits are sensed at the end of the calculation. In a sense, imaging of the states for the quantum computer is equivalent to the readout process of the computer. In this talk, the present results, including the details of the readout method, of the Josephson junction based qubit system is discussed.

SAMPLING ELECTRON DYNAMICS IN ATOMS IN REAL-TIME WITH SUB-FEMTOSECOND RESOLUTION

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With today's laser sources we are able to produce ultra-short pulses consisting only of a few wave-cycles with durations of about 5 femtoseconds($=10^{-15}$ s) in the near infrared spectral region. We utilize these pulses to create high order harmonics of the driver laser frequency in a highly nonlinear light-matter interaction in a noble gas jet inside vacuum. This process enables us to extract even shorter pulses by filtering the high energy part of the harmonic radiation in the XUV region at about 13nm, which yields pulses with approx. 250 attoseconds($=10^{-18}$ s) in duration. The very short visible and XUV pulses are well suited for pump/probe experiments in atomic and molecular systems. As the XUV pulse is created from the visible laser pulse, the timing jitter between them is rather low. Thus we achieve a temporal resolution of about 100 attoseconds and can utilize the setup to look at processes inside atoms and study electron dynamics in real time. Recent experiments in Xenon and Neon sample dynamics like photoionization, shake-up and auger processes on a sub-femtosecond timescale.

CORRECTION OF DISTORTIONS AND IMPROVEMENT OF INFORMATION CONTENT IN SATELLITE-ACQUIRED MULTI SPECTRAL IMAGES

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For a brief description of the methods employed in the present study, we perform image reconstruction from employing one reference image selected within the spectral range under consideration. The reconstruction is performed using an information-geometrical model describing the physical process of image formation in the short wave range of electromagnetic spectra (visual and neighboring infrared). The reconstruction of image pixel intensities is performed by arranging in ideal projection planes (PP) the locations needed for representation in different spectral channels to analyze and validate the available data. The model for reconstruction of the multispectral images was developed from physical principles. Scanner method was applied with coordinate-susceptibility photoreceivers (CSPR). A physics-based model for the formation of multispectral raster images with CSPR scanners in the electro-optic and infrared ranges can be developed by taking into account the tuning of optic-mechanic

scanner scheme. By using basic optic principles, the conformity between points on the earth surface and scanner sensitivity element (SE) can be established. One may note that each SE is fixing the electromagnetic radiation from some site as any cell projection on the earth surface where the center of projection is situated in the optic object-lens center.

Integration is performed on each cell square. This gives the mathematical model for the formation of digital images from CSPR equipped scanners in the multi spectral regime. It also enables explaining the reasons for distortions in these images. It may be noted that different projection distortions caused by optic-mechanic tuning scanner lead to displacements at the subpixel level.

Due to construction peculiarities characterizing the satellite and the sensor, the intensity distribution captured on the image plane will suffer distortions due to mixing of images collected along the different spectral channels. A method for the correction of distortions is to select the intensity distribution on one channel as the basic image and construct the intensity distribution data on other channels by image processing operations. Thus the method offers correction in the case of point displacement between different spectral channels due to diffraction effects and spatial coordinate-susceptibility of photo receivers causing positioning instability during sensing.

REMOTE CONTROL TECHNOLOGIES ON LAND COVER ELEMENTS CLASSIFICATION AND AGRARIAN RESOURCES ASSESSMENT

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Remote sensing of earth using multispectral observation platforms has now become an important part of a number of diverse human activities, such as cartography, monitoring of environment, assessment of security schemes, etc. The image databases that we use to validate our studies are obtained in the EO range of the electromagnetic spectrum with such satellites as: Sich-1M, Meteor - 3M, IRS (LISS), Spot, Landsat, Terra (Aster), etc. However, the present methods are more extensively studied with Ukrainian users satellites image databases such as Sich-1M and Meteor -3M.

A method for radiometric correction of multispectral images to ensure enhancement of information content and spatial resolution was developed. The method offers correction in the case of point displacement between different spectral channels due to diffraction effects and spatial coordinate-susceptibility of photo receivers causing positioning instability during sensing.

As applications of this method, some case studies on land cover elements classification and agrarian resources assessment are worked out. In particular the complex biophysical measurements including the vegetation structure like NDVI was assessed for some areas of representing various landscapes, geographic and climate zones. Formal sites are based on high-resolution remote sensing, ancillary and field plot data.

The development of the test site database for selected Ukrainian territories is intended to represent the earth's diversity of land covers and types of land cover change. The site network represents global, regional and local change processes due to both natural and anthropogenic factors. Test criteria include phenological class (seasonal grassland, deciduous forest), anthropogenic (urbanization, agriculture, conversion, biomass burning), interface (land/snow, land/water), biotic (insect and pathogen), and hydrologic (seasonal inundation) representation. A number of critical sites and "hotspots" sites is included in the network because of their particular conservation, political, economic and social significance. As applications of this method, some case studies on potentially dangerous landslide areas selection and classification of land cover elements classification have been developed as well.

NONLINEAR RESPONSE OF STRONGLY CORRELATED MATERIALS TO LARGE ELECTRIC FIELDS

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The electron-electron interaction in strongly correlated electron materials is so strong, that it is of primary importance in determining how the materials behave. These materials can be tuned to pass through a metal-insulator transition as a function of doping, pressure, or temperature, which makes them strong candidates for use in so-called “smart materials” that can change their properties to respond to the particular needs of a device. We consider a model system described by the Falicov-Kimball Hamiltonian[1] in the presence of an external field that is spatially uniform but can be time dependent, and can have an arbitrary large amplitude. A number of different approaches is employed to numerically solve this problem, all based on a non-equilibrium generalization of dynamical mean field theory, which has been used for equilibrium many-body problems for the last 20 years. The generalization is based on a time-dependent approach and requires the discretization of the time axis[2]. Our solution is obtained by inverting over 20,000 dense general complex matrices of size up to 2200x2200 for each iteration of the algorithm. We usually need between 15 and 30 iterations before the results have converged. The central issue is the accuracy of the data obtained for a given time-step and scaling to the zero-step-size limit.

Employing a massively parallel algorithm we exactly solve for the response of these strongly correlated materials to the presence of a large electric field, including all nonlinear and non-equilibrium effects. Our algorithm breaks into two portions, one serial and one parallel. By carefully controlling the communications part of the code, we were able to achieve essentially linear scale up of the parallel part of the code, which produced good scaling behavior for up to 3000 processors, although most production runs employed about 1500 processors.

We will briefly explain the formalism and the numerical algorithm, discuss the scalability of the data, and present the results for the current as a function of time for a variety of different systems, which represent the range of different behaviors near a Mott metal-insulator transition.

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